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January 13, 2000

BOX: PATENT APPLICATION
Assistant Commissioner for Patents
Washington, D.C. 20231

Re: Application of Kiyoshi **TAKEI**, Nong **CHEN**, Yoshiaki **WATANABE** and Kiyofumi **CHIKUMA**
DISTRIBUTED FEEDBACK TYPE SEMICONDUCTOR LASER DEVICE AND METHOD OF MANUFACTURING THE SAME
Our Reference: Q57433

Dear Sir:

Attached hereto is the application identified above including the specification, claims, executed Declaration and Power of Attorney, four (4) sheets of drawings, executed Assignment and PTO Form 1595.

The Government filing fee is calculated as follows:

Total Claims	5 - 20 =	0 x $18 =	$ 000.00
Independent Claims	2 - 3 =	0 x $78 =	$ 000.00
Base Filing Fee	($690.00)		$ 690.00
Multiple Dep. Claim Fee	($260.00)		$ 000.00
TOTAL FILING FEE			**$ 690.00**
Recordation of Assignment Fee			$ 40.00
TOTAL U.S. GOVERNMENT FEE			**$ 730.00**

Checks for the statutory filing fee of $ **690.00** and Assignment recordation fee of $ **40.00** are attached. You are also directed and authorized to charge or credit any difference or overpayment to Deposit Account No. 19-4880. The Commissioner is hereby authorized to charge any fees under 37 C.F.R. 1.16 and 1.17 and any petitions for extension of time under 37 C.F.R. 1.136 which may be required during the entire pendency of the application to Deposit Account No. 19-4880. A duplicate copy of this transmittal letter is attached.

Priority is claimed from:

Japanese Patent Application	**Filing Date**
11-38281	February 17, 1999

The priority document will be submitted at a later date.

Respectfully submitted,
SUGHRUE, MION, ZINN, MACPEAK & SEAS
Attorneys for Applicant(s)

By Darryl Mexic
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DM:crh

DISTRIBUTED FEEDBACK TYPE SEMICONDUCTOR LASER DEVICE AND METHOD OF MANUFACTURING THE SAME

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The present invention relates to a method of manufacturing Distributed FeedBack (hereinafter abbreviated as "DFB") type semiconductor laser devices and to a DFB type semiconductor laser device.

2. RELATED ART

DFB type semiconductor laser devices are well-known as devices for use with light communications systems such as light CATV, shortwave lasers making use of SHG (Second Harmonic Generation) devices, pump light sources for small-sized solid-state lasers, light measurement arts or the like.

Fig. 1 shows a conventional DFB type semiconductor laser element. Laminated on a substrate 1 composed of n^+-InP are a lower clad layer 2 composed of n-InP, a lower guide layer 3, an activated layer 4, and an upper guide layer 5, which are composed of InGaAsP having different compositions. Further above the upper guide layer 5 is an upper clad layer 6 composed of p-InP partly having a ridge. Provided on flat portions on both sides of the upper clad layer 6 is a grating layer 6a and provided on top of the ridge is a contact layer 7 composed of InGaAsP. Arranged on the grating layer 6a is an inorganic protective layer 8 composed of a silicon compound such as water glass.
Also, electrodes 20, 21 are formed on the contact layer 7 and on an underside of the substrate 1.

With conventional DFB type semiconductor laser devices, a ridge is formed to confine a generated light in a three

dimensional space. However, a process of forming such a ridge, and a process of forming a window, which is required for an electrode to be provided on the top of the ridge, with high accuracy while aligning it, are extremely complicated and responsible for an increased cost.

The present invention has been developed in view of the above-described problem, and is aimed at providing a DFB type semiconductor laser device, which can be readily manufactured without any complicated process, and also provides a method of manufacturing the same.

A DFB type semiconductor laser device according to the present invention comprises a laser substrate, a grating layer, an insulating layer and an electrode layer, which are laminated in this order, the insulating layer including a through groove or grooves extending to the grating layer in a direction, along which a resonator of the laser device is formed, and the electrode layer contacting the grating layer and the clad layer.

Also, a method of manufacturing a DFB type semiconductor laser device, according to the present invention, comprises the steps of forming a laser substrate including at least a waveguide layer and a clad layer, forming a grating layer on the top surface of the laser substrate; forming an insulating layer having a through groove or grooves extending to the grating layer in a direction, along which a resonator of the laser device is formed, forming an electrode layer made of a high refractive material on the insulating layer, and forming a further electrode layer on the bottom surface of the laser substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view showing a conventional DFB type

semiconductor laser device.

Fig. 2 is a perspective view showing a DFB type semiconductor laser device according to the present invention.

Fig. 3 is a perspective view showing a laser substrate in a process of forming a grating layer in the manufacturing method according to the present invention.

Fig. 4 is a perspective view showing a substrate in the state in which the grating layer has been formed, in the manufacturing method according to the present invention.

Fig. 5 is a perspective view showing a laser substrate in a process of forming through grooves on an insulating layer, in the manufacturing method according to the present invention.

Fig. 6 is a perspective view showing a laser substrate in the state in which the through grooves are formed on the insulating layer, in the manufacturing method according to the present invention.

Fig. 7 is a perspective view showing a laser substrate in the state in which electrodes are vapor deposited, in the manufacturing method according to the present invention.

Fig. 8 is a perspective view showing a process of obtaining a finished semiconductor laser device by subdividing a bulk, in which a grating layer, an insulating layer and an electrode layer are laminated on the laser substrate, in the manufacturing method according to the present invention.

Fig. 9 is a view showing the power distribution of a semiconductor laser device according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the present invention will be described below with reference to Figs. 2 to 8.

As shown in Fig. 2, a lower clad layer 2 composed of n-InP, a lower guide layer 3, an activated layer 4, and an upper guide layer 5, which are composed of InGaAsP having different compositions (these three layers are hereinafter collectively referred to as a waveguide layer), and an upper clad layer 6 composed of p-InP are laminated in this order on a substrate 1 composed of n^+-InP.

A contact layer 7 composed of InGaAs is formed to provide a grating layer 7a on the upper clad layer 6. The grating layer 7a is constructed such that a plurality of ridges having a substantially rectangular-shaped cross-section are aligned periodically or, in other words, at spaced intervals to a direction in which a laser resonator is formed. Here, a grating may be formed on a part of the upper clad layer 6 to provide a grating contiguous to the contact layer 7.

Further, two inorganic protective layers 8 composed of a silicon compound such as water glass are formed in strips on the grating layer 7a to be parallel to the direction in which the resonator is formed. The inorganic protective layers 8 include through grooves leading to the grating layer 7a.

Further, a p-side electrode layer 20 composed of a metal, such as Ti and Cr, having a high refractive index, is provided on the inorganic protective layers 8 and on the grating layer 7a in the through groove region of the inorganic protective layers 8. A metallic material, composing the electrode layer 20, enters the through groove region through the grating layer 7a, so that the portion of the electrode layer 20 contacts the upper clad layer 6. Also, an n-side electrode layer 21 is formed on the bottom surface of the substrate 1.

With such an arrangement, the light generated in the waveguide layer is confined by the electrode layer 20, which contacts the upper clad layer 6 and has a high refractive index. Therefore, the upper clad layer 6 must have such a thickness that the light generated in the waveguide layer can interact with the electrode layer 20, with the upper clad layer 6 therebetween. Therefore, such a thickness is preferably 0.5 μm or less.

An explanation will be given hereinafter of the method of manufacturing a semiconductor laser device, according to the present invention.

As shown in Figs. 3 and 4, a wafer made of an InP crystal substrate having the face orientation (1 0 0) is prepared. After the surfaces of the wafer is cleaned by chemical etching, the epitaxial growth method, the liquid phase growth method, the organic metal vapor growth method, the molecular beam growth method or the like is used to form the SCH (Separate Confinement Hetero-structure) activated layer region, the clad layer, the contact layer and so on.

For example, the lower clad layer 2 composed of n-InP is formed to provide a film, having an optional thickness, on the surface (1 0 0) of the n^+-InP substrate 1. The lower guide layer 3, the activated layer 4 and the upper guide layer 5, which are composed of $In_{1-x}Ga_xAs_{1-y}P_y$ having different compositions, are formed on the lower clad layer to provide a film having a total thickness of 0.2 μm.

Further, the upper clad layer 6 composed of p-InP is formed to provide a film. As described above, the upper clad layer 6 must have such a thickness that the light generated in the waveguide layer interacts with the electrode layer 20, which is

on the upper clad layer 6 and has a high refractive index. Therefore, such a thickness is preferably 0.5 μm or less.

Further, the contact layer 7 composed of p-InGaAsP or p^+-InGaAs is formed to provide a film on the upper clad layer 6, thus forming a multilayer structured substrate having a laser construction.

Further, a protective film 11 composed of SiO_2 is formed on the multilayer structured substrate. The protective film 11 is useful in preventing P desorption in the multilayer structured substrate and as an etching mask. Also, the protective film 11 is useful in obtaining a uniform film of a high resolution EB resist, which needs high temperature baking in the next process. Subsequently, an EB draughting resist is coated on the protective film 11, and then baked to form a resist layer 12.

Here, EB draughting is performed in a cycle conformed to the laser oscillation wave length with lines along the direction [0 1 1] of the crystal orientation of the substrate 1, thus forming a latent image of a grating having a periodic construction, which changes in a cycle Λ, on the resist layer 12 in the direction [0 -1 1] of the substrate 1.

Generally, a ridge constraction in a DFB type semiconductor laser has a ridge which is provided at periodic or given intervals in a cycle Λ in a direction in which laser light is transmitted. Therefore, the refractive index also changes periodically and the reflectance increases in a wave length, in which light reflected periodically coincides in phase (Bragg reflection), so that laser oscillation is generated. Accordingly, an oscillating wave length of a DFB type semiconductor laser is determined by a cycle Λ of a periodic

construction, so that a single longitudinal mode can be generally obtained in a condition in which $\Lambda = m\lambda/2n$ is satisfied. Here, m indicates an integer, λ an oscillating wave length in vacuum, and n is an effective refractive index of a laser medium. With respect to the laser, the cycle Λ is determined taking into account refractive indexes, film thicknesses and aspect ratios of the activated layer 4, the lower clad layers 2 and 6, a reflection coefficient of a resonator (a cleavage plane), and an optically coupling factor in a transverse direction.

A process of forming the grating layer 7a comprises transferring a grating of the resist layer 12 onto the SiO_2 protective film 11 by means of CF_4 dry etching, and performing Cl_2 dry etching on the contact layer 7 composed of p^+-InGaAs to form the grating layer 7a having a substantially rectangular-shaped cross section.

Further, the protective film 11 is removed. Electron beam lithography as well as photolithography may be used to form the grating layer 7a.

Subsequently, as shown in Figs. 5 and 6, a silicon compound or the like is coated on the grating layer 7a and cured to form the inorganic protective layers 8. Further, a resist mask 13 composed of SiO_2, TiO_2 and so on is applied on the protective layers to leave gaps in a strip shape in the direction [0 1 1] of the InP crystal substrate 1. The gaps define a transverse width of the through grooves, which is associated in confining the light, generated in the waveguide layer, in the transverse direction. After the inorganic protective layers 8 are subjected to etching until the surface of the grating layer 7a is

exposed, the resist mask 13 is removed to thereby form the through grooves on the inorganic protective layers 8.

Subsequently, as shown in Fig. 7, the p-side electrode layer 20 composed of Ti/Au having a high refractive index is vapor deposited on the inorganic protective layer 8 and the grating layer 7a. Further, the bottom surface of the substrate 1 opposite to the surface thereof, on which the waveguide layer and the like are formed is polished and the n-side electrode layer 21 composed of Ti/Au is vapor deposited on the bottom surface to provide a bulk.

Subsequently, as shown in Fig. 8, scribe lines 14 having a length corresponding to the laser wave length are marked on an end of the bulk thus formed in the above described manner, and the bulk is subdivided into bar-shaped bodies 15 with the scribe lines 14 as origins. Further, AR coating and HR coating are applied on end surfaces 16, 17 of the bar-shaped bodies extending in a direction in which a resonator is defined and the bar-shaped bodies thus coated are cleaved to provide DFB type semiconductor laser devices 18.

Fig. 9 is a view showing a power distribution of a semiconductor laser device thus obtained in the direction in which the resonator is formed. In the drawing, a center of the waveguide layer is taken as an origin. Also, thicknesses of the upper clad layer 6, the contact layer 7 and the inorganic protective layers 8 and a transverse width of the through grooves are 0.4 μm, 0.05 μm, 0.5 μm and 4 μm, respectively. It is found that the laser light generated is confined in lower portions of the through groove region on the insulating layer in a three dimensional fashion.

The present invention can attain confinement of generated light in the three dimensional fashion without the formation of any ridge. Therefore, production efficiency is enhanced because any complicated process or the like for formation of such a ridge is not needed.

WHAT IS CLAIMED IS:

1. A DFB type semiconductor laser device comprising a laser substrate, a grating layer, an insulating layer and an electrode layer are laminated in order, the insulating layer including at least one through groove extending to the grating layer in a direction in which a resonator of the laser device is formed, the electrode layer contacting the grating layer and the clad layer.

2. The DFB type semiconductor laser device according to claim 1, wherein the laser substrate comprises a waveguide layer composed of at least InGaAsP and a clad layer composed of p-InP, and the grating layer is composed of InGaAs.

3. The DFB type semiconductor laser device according to claim 2, wherein the clad layer has a maximum thickness of substantially 0.5 μm.

4. A method of manufacturing a DFB type semiconductor laser device, comprising the steps of forming a laser substrate including at least a waveguide layer and a clad layer; forming a grating layer on a top surface of the laser substrate; forming an insulating layer having at least one through groove extending to the grating layer in a direction in which a resonator of the laser device is formed; forming an electrode layer made of a high refractive material on the insulating layer; and forming a further electrode layer on a bottom surface of the laser substrate.

5. The method according to claim 4, wherein the step of forming the grating layer comprises the steps of forming a contact layer on the clad layer of the laser substrate, and removing a portion of the contact layer by lithography to form a plurality of parallel ridges aligning in parallel to one another in the direction in which the resonator of the laser device is formed.

ABSTRACT OF THE DISCLOSURE

A DFB type semiconductor laser device can be readily manufactured obviating the need to form a ridge without any complicated process, and a method of manufacturing the same is described. The DFB type semiconductor laser device includes a laser substrate, a grating layer, an insulating layer and an electrode layer, which are laminated in the given order, the insulating layer including a through groove or grooves extending to the grating layer in a direction in which a resonator of the laser device is formed, the electrode layer contacting the grating layer and the clad layer.

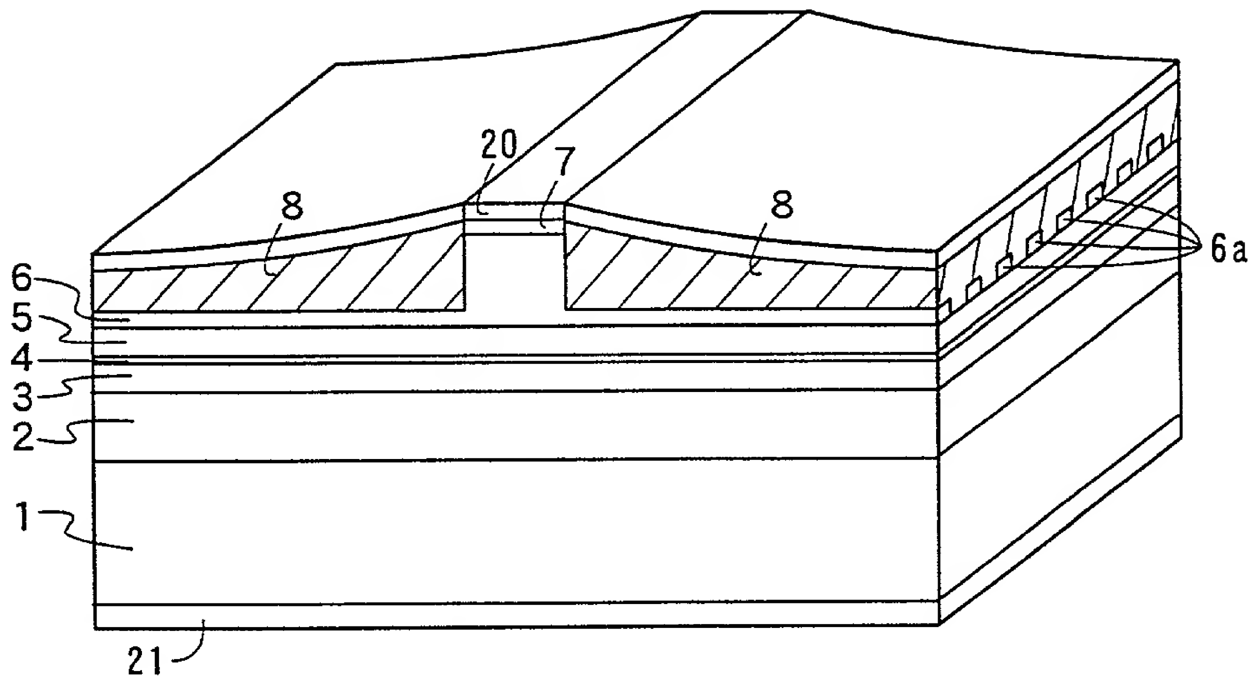


FIG.1

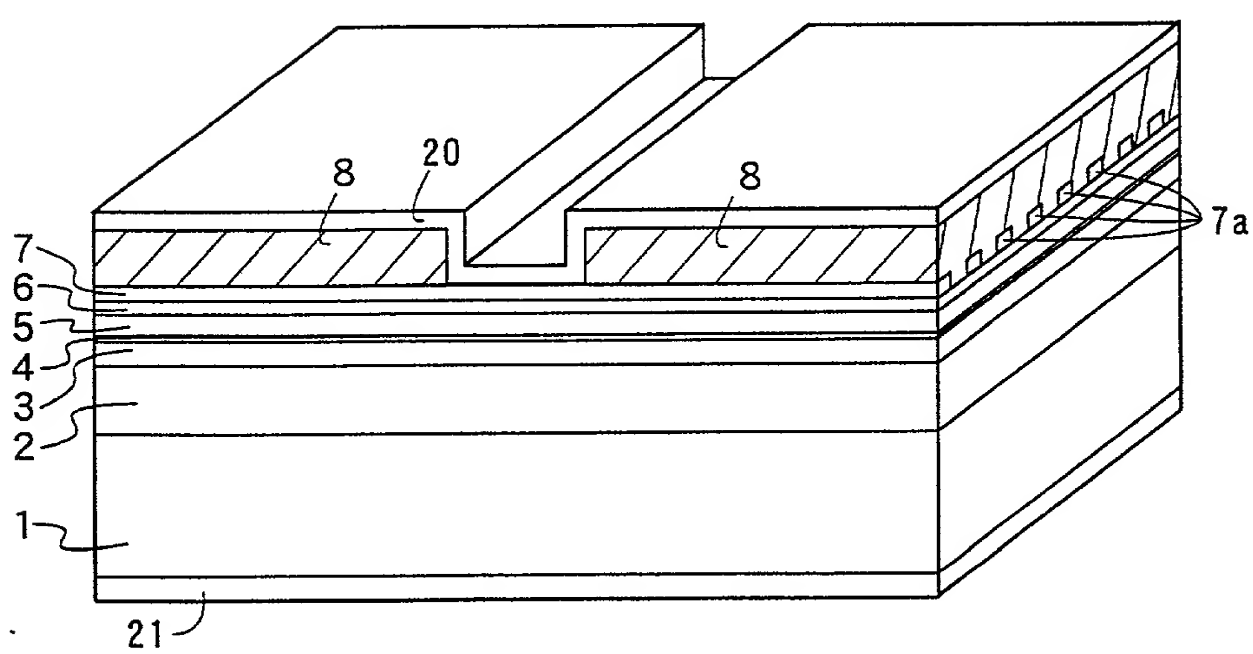


FIG.2

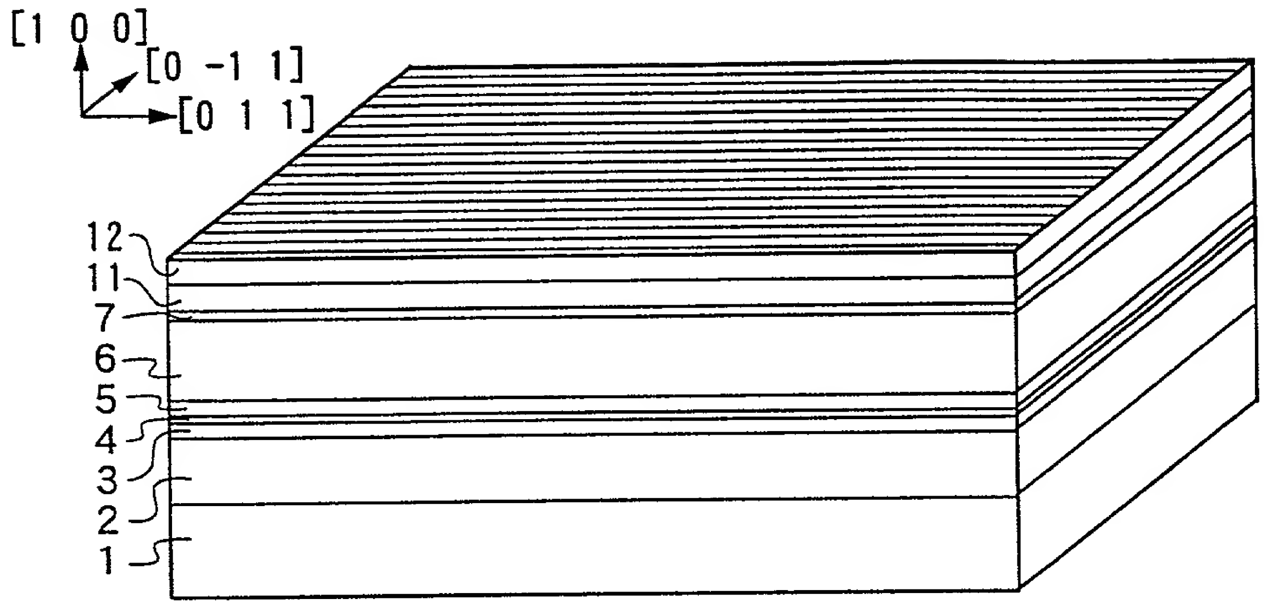


FIG.3

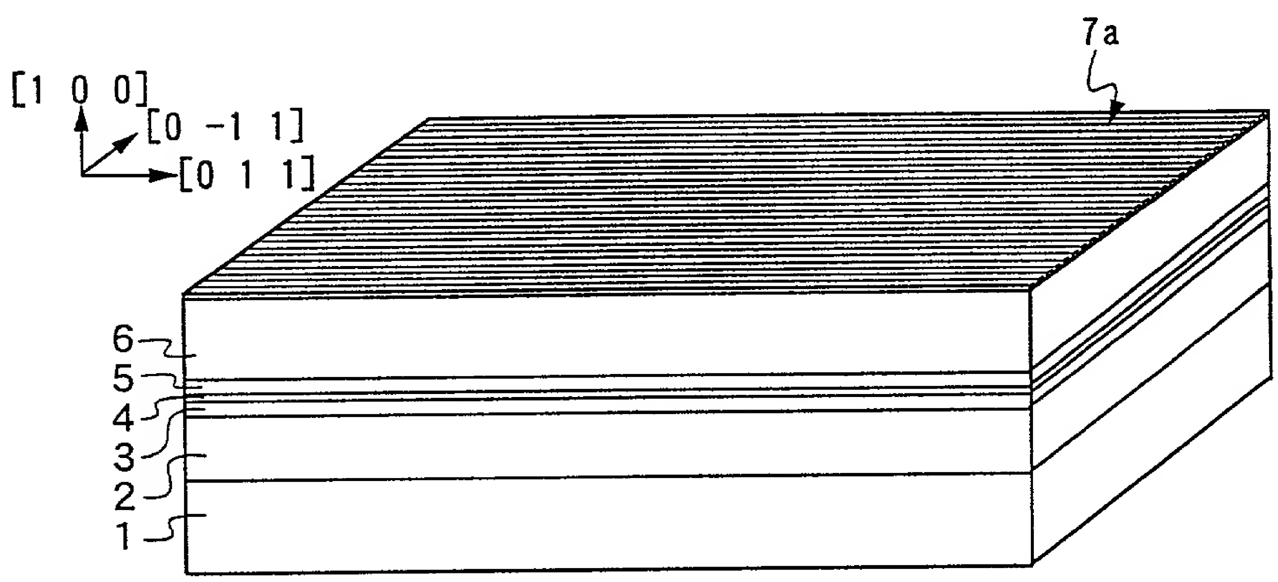


FIG.4

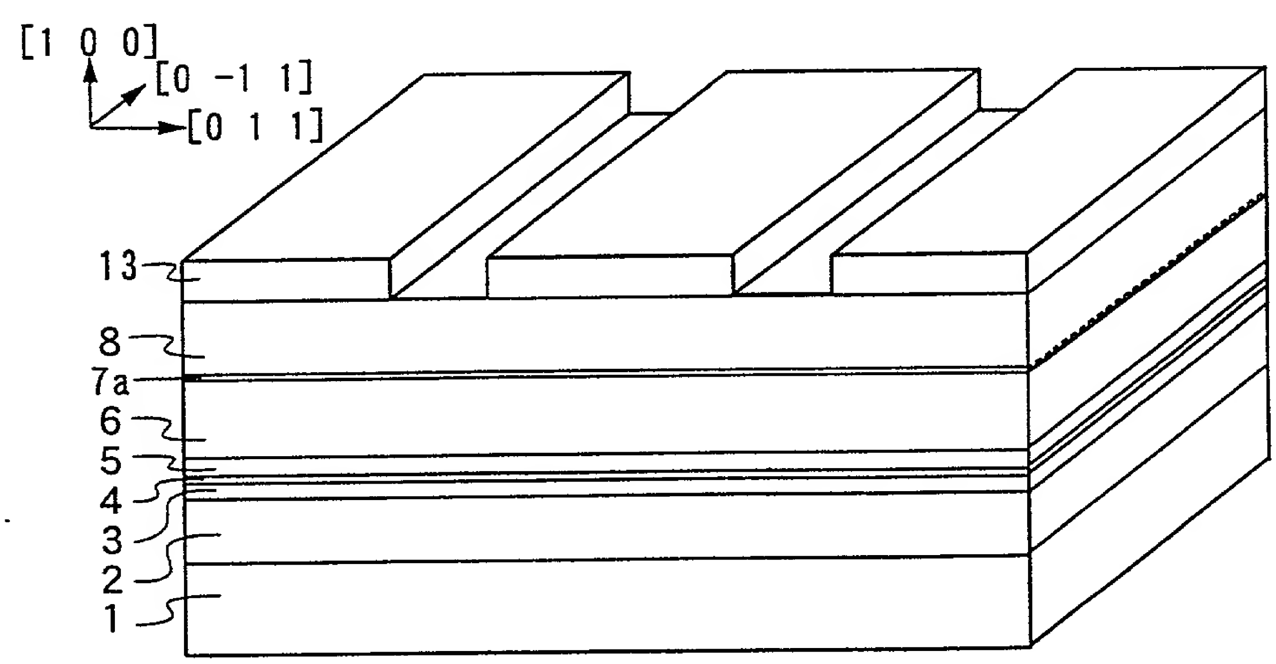


FIG.5

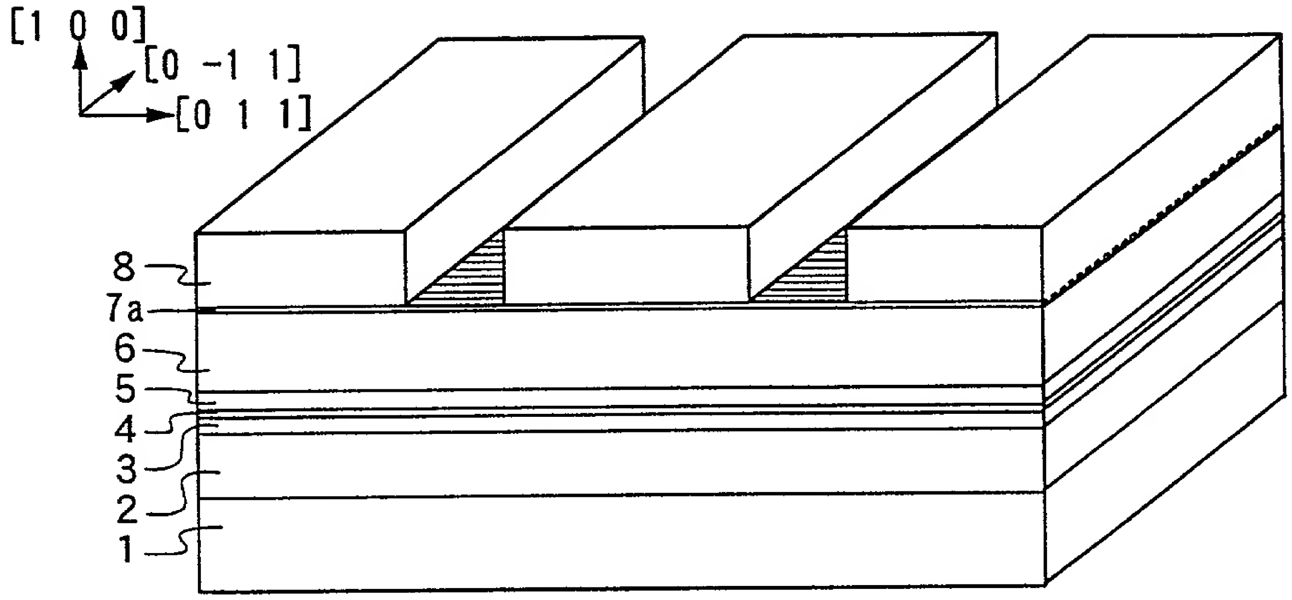


FIG.6

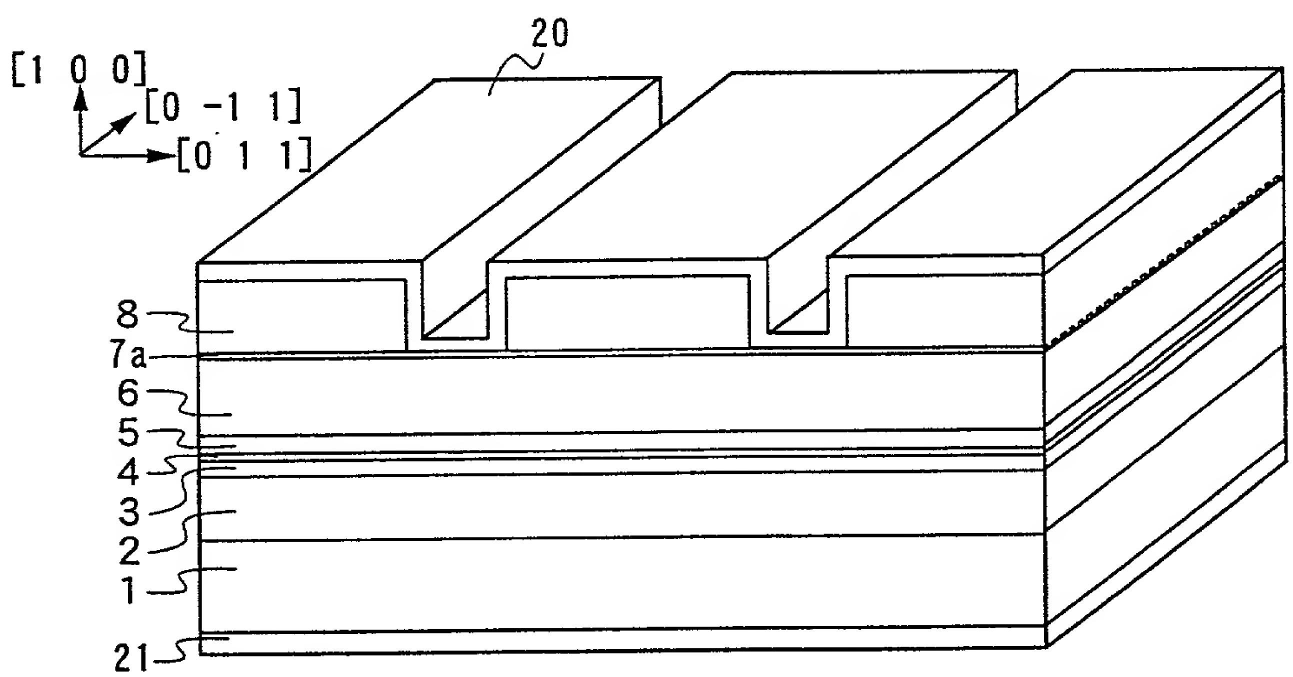


FIG.7

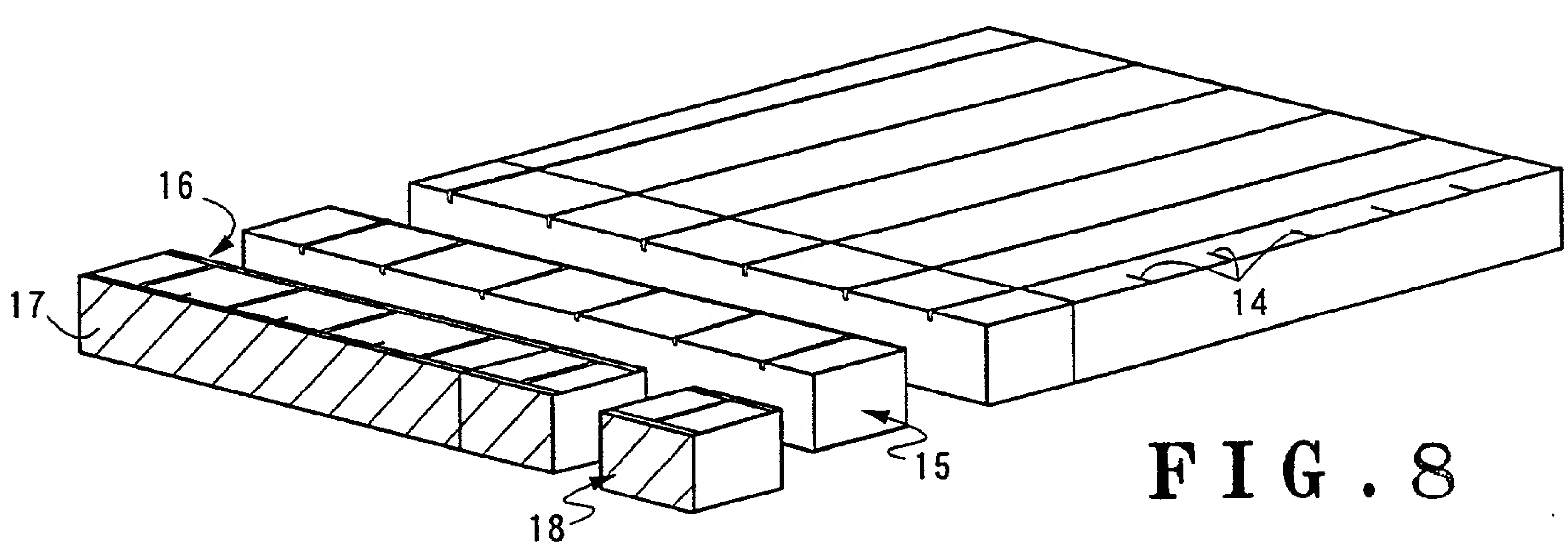
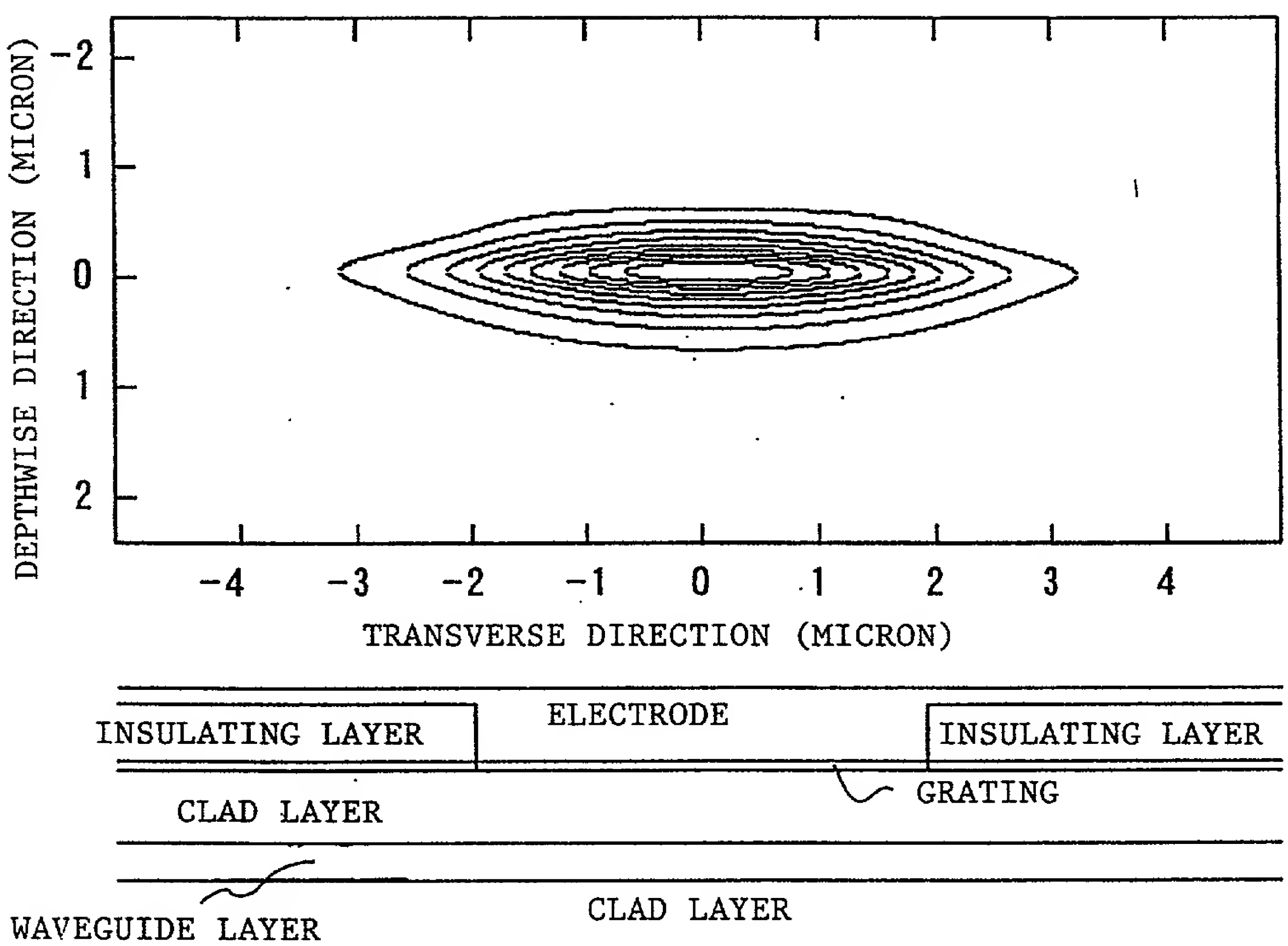


FIG.8

FIG.9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INSULATING LAYER
GRATING
CLAD LAYER
WAVEGUIDE LAYER
CLAD LAYER

SOLE/JOINT

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name: that I verily believe I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural names are listed below) of the subject matter claimed and for which a patent is sought in the application entitled:

DISTRIBUTED FEEDBACK TYPE SEMICONDUCTOR LASER DEVICE AND METHOD OF MANUFACTURING THE SAME

which application is:

x the attached application (for original application)

___ application Serial No. ___________. filed ___________, and amended on ___________ (for declaration not accompanying application)

that I have reviewed and understand the contents of the specification of the above-identified application, including the claims, as amended by any amendment referred to above; that I acknowledge my duty to disclose information of which I am aware which is material to the patentability of this application under 37 C.F.R. 1.56, that I hereby claim foreign priority benefits under Title 35, United States Code §119, §172 or §365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified on said list any foreign application for patent or inventor's certificate on this invention having a filing date before that of the application on which priority is claimed:

Application Number	Country	Filing Date	Priority Claimed (yes or no)
11-38281	Japan	February, 17, 1999	Yes

I hereby claim the benefit of Title 35, United States Code §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in a listed prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge my duty to disclose any information material to the patentability of this application under 37 C.F.R. 1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application Serial No.	Filing Date	Status (patented, pending, abandoned)

I hereby appoint John H. Mion, Reg. No. 18,879; Donald E. Zinn, Reg. No. 19,046; Thomas J. Macpeak, Reg. No. 19,292; Robert J. Seas, Jr., Reg. No. 21,092; Darryl Mexic, Reg. No. 23,063; Robert V. Sloan, Reg. No. 22,775; Peter D. Olexy, Reg. No. 24,513; J. Frank Osha, Reg. No. 24,625; Waddell A. Biggart, Reg. No. 24,861; Robert G. McMorrow, Reg. No. 19,093; Louis Gubinsky, Reg. No. 24,835; Neil B. Siegel, Reg. No. 25,200; David J. Cushing, Reg. No. 28,703; John R. Inge, Reg. No. 26,916; Joseph J. Ruch, Jr., Reg. No. 26,577; Sheldon I. Landsman, Reg. No. 25,430; Richard C. Turner, Reg. No. 29,710; Howard L. Bernstein, Reg. No. 25,665; Alan J. Kasper, Reg. No. 25,426; Kenneth J. Burchfiel, Reg. No. 31,333; Gordon Kit, Reg. No. 30,764; Susan J. Mack, Reg. No. 30,951; Frank L. Bernstein, Reg. No. 31,484; Mark Boland, Reg. No. 32,197; William H. Mandir, Reg. No. 32,156; Scott M. Daniels, Reg. No. 32,562; Brian W. Hannon, Reg. No. 32,778 and Abraham J. Rosner, Reg. No. 33,276, my attorneys to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith, and request that all correspondence about the application be addressed to SUGHRUE, MION, ZINN, MACPEAK & SEAS, 2100 Pennsylvania Avenue, N.W., Washington, D.C. 20037-3202.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Date Dec. 14, 1999

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